with sufficient accuracy from the formula D = 2pc/eH, where H is the field at the mean distance from the sample axis, and 2p is the dimension of the orbit in momentum space in the direction of the axis. It is easy to see that in the case when the orbit is located on a convex side of the Fermi surface, the maximum value of D will be the same for a finite interval of field directions in the sample (see Fig. 1b, in the bottom of which is shown part of the Fermi surface with the orbits corresponding to different sections of the sample.

When d < D, the effective electrons accelerated in the skin layer collide with the n-s boundary and at the investigated temperatures they should be reflected almost completely. If d > D/2, the electrons return to the skin layer after a twofold reflection, making practically the same contribution to the current as in the case when d > D (scheme b of Fig. 2).

When J decreases to a value such that the radial dimension of the trajectory of the reflected quasiparticles becomes comparable with d, the particle fall in the skin layer after the first reflection, making a contribution of opposite sign to the surface current (scheme a in Fig. 1), and this should lead to the occurrence of the SRE line at a value of J determined by the condition d(J) = pc/eH, where H is the field at a distance d/2 from the surface of the sample. This line should obviously be missing in the usual specular reflection.

The numbers 1, 2, and 3 on the curve for T = 1.6°K on Fig. 2 denote the positions of the lines calculated from the values of p for the sections 1_1, 2_1, and 3_1 from [1]. The close agreement between the line positions and the calculated ones confirms the reflection law proposed by Andreev.

When the sensitivity is increased threefold, the curve of Fig. 2 shows clearly the RSE peak at d = D for the total cross section 1 (scheme c of Fig. 2). The appearance of this line is apparently connected with a change of the structure of the "burst" of the radio-frequency current (see [7]), which is present in the metal at a distance D from the surface, when the region of the burst crosses the n-s boundary, with the reflected part of the burst superimposed on the non-reflected part. It is obviously possible to observe an entire series of lines with rapidly decreasing intensities in those cases when x the n-layer thickness subtends m/2 extremal orbits (m is an integer).

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BIRESONANT FREQUENCY DOUBLING BY AN ANTIFERROMAGNET

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We have observed experimentally "biresonant" frequently doubling by an antiferromagnet, predicted by Ozhogin [1]. This effect is connected essentially with the form of the antiferromagnetic resonance (AFMR) spectrum, and can be observed in antiferromagnets hav ing an anisotropy of the "easy plane" type.

From the solution of the linearized Landau-Lifshitz equations for the two sublattice model of such an antiferromagnet it follows that the AFMR spectrum [2] consists of two branches, whose frequencies are determined as follows (when $H \perp C$):

$$(\nu_1/\gamma)^2 = H(H + H_D) + H_\Delta^2 \tag{1}$$

$$(\nu_2/\gamma)^2 = 2H_A H_E + HH_D \quad . \tag{2}$$

It follows from the same equations, in addition, that different components of the vectors $\vec{\ell} = \vec{\ell}_0 + \vec{\lambda}$ and $\vec{m} = \vec{m}_0 + \vec{\mu}$ take part in the oscillations of the spins corresponding to the first and second branches of the spectrum, namely, the oscillations in the first branch are described by the variables μ_y, μ_z, and λ_x, while the oscillations in the second branch are described by μ_x, λ_y, and λ_z. An examination of the nonlinearized equations of motion of the momenta shows that when oscillations corresponding to the first branch are excited at the frequency $\nu = \nu_1$, the components μ_x, λ_y, and λ_z, which oscillate at the frequency 2ν, also take part in the motion of the spins. The oscillations of the component μ_x should cause the antiferromagnet to emit electromagnetic waves of double the frequency (relative to the exciting one). The radiation amplitude increases resonantly if the radiated frequency is close to the natural frequency of the second branch, i.e., when the following condition is satisfied:

$$2\nu_1 = \nu_2. \quad (3)$$

This phenomenon was considered theoretically by Ozhogin and called by him "biresonant frequency doubling."

The present paper is devoted to an experimental study of doubling of microwave frequencies by an antiferromagnet. The investigated objects were antiferromagnets with anisotropy of the "easy plane" type, $MnCO_3$ and $CsMnF_3$,[1] both AFMR branches of which have been well investigated [3, 4, 5, 6]. The measurements were made with a magnetic spectrometer similar to that described in [7]. The microwave source was a pulsed magnetron for the 8 mm band (MI-88). The investigated crystal was placed in a short-circuited 8-mm waveguide in such a way that H was in the basal plane and h_{micro} was perpendicular to it. The double-frequency signal was filtered from the fundamental one with a waveguide operating beyond cutoff, and was fed first to a detector and then to a V4-1A peak voltmeter. The amplitude of the doubling signal, as a function of the magnetic field, was recorded with an x-y plotter. The absolute power radiated at the second harmonic was not measured.

To satisfy the condition under which it is possible to observe the biresonant frequency doubling (2), we made use of the fact that ν_2, which is determined by the gap in the spectrum, depends on the temperature and vanishes at $T = T_N$, whereas ν_1 varies little with temperature. Therefore at ν = 37 GHz the condition (3) can be satisfied for $CsMnF_3$ at T_{Br} = 41.8°K and for $MnCO_3$ at T_{br} = 28.2°K.

To obtain such temperatures, we used a vacuum cryostat [6] with liquid neon or liquid helium as the cooling agent.

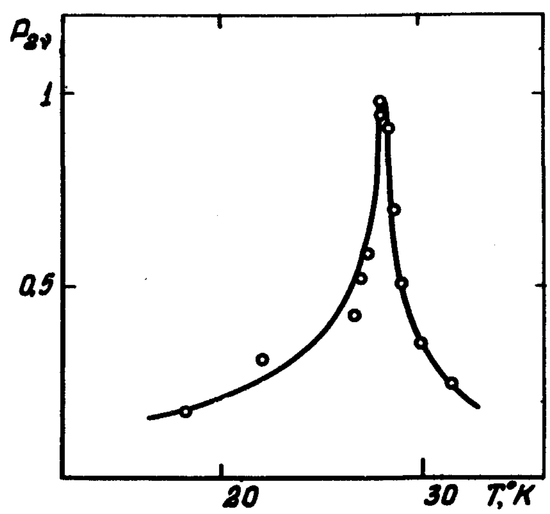

Fig. 1. Temperature dependence of double-frequency signal for $MnCO_3$.

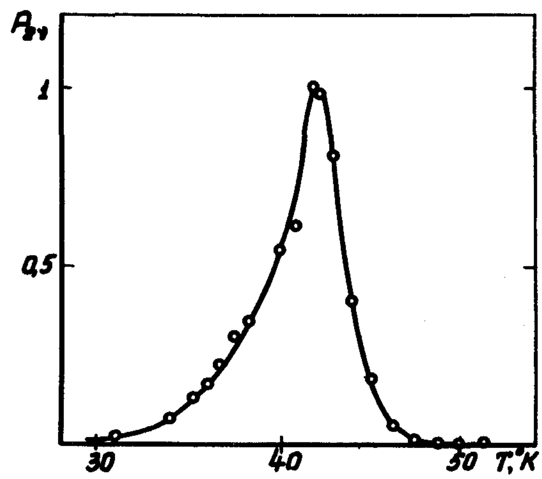

Fig. 2. Temperature dependence of double-frequency signal for $CsMnF_3$.

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A double-frequency signal appeared at $T < T_N$ at a magnetic field intensity H corresponding to excitation of the oscillations of the first branch. No frequency doubling was observed in the paramagnetic region.

Figures 1 and 2 show the temperature dependences of the double-frequency signal amplitudes for $MnCO_3$ and $CsMnF_3$. A sharp increase of the amplitude and a change of the signal phase by π were observed for both investigated antiferromagnets following smooth variation of the temperature in the vicinity of $T = T_{br}$, corresponding to biresonant frequency doubling.

The magnitude and form of the "biresonance" peak agree with the theory if the experimental values are used for the widths of the resonance lines and for the temperature dependence $\nu_2(T)$.

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INFLUENCE OF ROTATIONAL DIFFUSION ON THE PARAMAGNETIC RESONANCE LINE SHAPE

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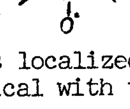
The EPR spectrum of paramagnetic particles in the dilute state in viscous media is determined by the degree of averaging, by the rotational motions of the particles (with a correlation time τ_c), of the anisotropy of the electronic Zeeman (tensor g_{ik}) and hyperfine (tensor f_{ik}) interactions [1]. Usually the anisotropy of the interactions is characterized by the parameter

$$\sigma = max\left\{ H_0 \left| \beta \left(g_{zz} - \frac{g_{xx} + g_{yy}}{2}\right)\right|, \quad \left| f_{zz} - \frac{f_{xx} + f_{yy}}{2}\right| \right\},$$

where β is the Bohr magneton, H_0 the constant magnetic field, and g_{ij} and f_{ii} the principal values of the tensors.

Although it is of considerable interest (for example, for the study of high-molecular compounds [2]), there is no exact theory of EPR, and the experimental data are very scanty outside the region $\sigma\tau_c < 1$ where perturbation theory holds (fast rotations). To calculate the line shape in the region of slow rotations, $\sigma\tau_c \geq 1$, it is necessary to specify a concrete model of the random process [3, 4]. We shall show that the EPR line shape in a viscous medium can be well described by a theory that regards rotational motions as random changes of the molecule orientation by finite angles.

We chose as the paramagnetic particle the imino-acid radical [5, 6]



The unpaired electron in such radicals is localized mainly at the nitrogen nucleus. To simplify the calculations, we used a radical with the rare isotope N^{15} (nuclear spin $I = 1/2$).